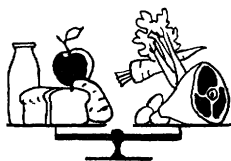


The Story of Nutrition

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THIS is the story of man's long search for exact knowledge of the food his body needs.

It is a story of laboratories, experiments, failures, successes, and discoveries. It is even more a story of men and women with curiosity, ideas, persistence, and a driving desire to help people live better.

It is a story of a fight against ignorance and superstitions and the strange ideas people always have had—now, too!—about the things they eat.

It is an old story that could begin with the first man and the little he knew beyond the fact that he liked to eat.

It is, though, primarily a story of accomplishments in this century—indeed, in the last few years; a story so new that it is far from its end.

Although for centuries people tried to solve some of their problems of what to eat and how much and why, they made little progress until chemistry was well developed and we could analyze foods and know what they are made of. We also had to wait until physiology became a science that could provide understanding of the human body and how it functions. We needed as well the contributions

of physics, medicine, agriculture, and biology.

Because it is a “new” science, then, let us begin with the man who has been called “the father of American nutrition” and later go back to the men and ideas that preceded him—for nutrition, like every science and almost every other great development, has been built on things that went before.

Wilbur Olin Atwater was born in 1844 in Johnstown, N.Y. He attended the University of Vermont and Wesleyan University in Middletown, Conn. For his thesis for his doctor's degree at Yale University in 1869 he—for the first time in this country—used modern methods to analyze corn fodder.

He went to Europe in 1869 to study agricultural and physiological chemistry at the Universities of Leipzig and Berlin. When the first experiment station in the United States was established at Middletown in 1875, he became its first director. He later became director of the Connecticut Agricultural Experiment Station at Storrs when it was organized in 1887.

His studies on the acquisition of atmospheric nitrogen by plants and on the composition of feeds, begun several

years earlier, he continued as part of the work at Storrs during the 14 years he was director. These investigations led to his interest in the composition of man's food.

Dr. Atwater made a series of analyses of fish for the United States Fish Commission and of the flesh of domestic animals for the Smithsonian Institution between 1879 and 1883. He conducted studies of the dietaries of people in Massachusetts and Canada.

Dr. Atwater returned to Europe in 1887. He worked in the laboratory in Munich where Carl Voit was doing outstanding work in studies of respiration—the exchange of gases between the blood and the tissues—and calorimetry, the measurement of heat, the first steps toward quantitative knowledge of nutritional requirements.

Another American student who worked in Dr. Voit's laboratory was Graham Lusk, who brought back with him a small model of a calorimeter Voit had made and later built others at Cornell University Medical College in New York City for studies with dogs and children. We shall come back to Dr. Voit later.

Dr. Atwater also returned to this country inspired to do further calorimetry studies at Wesleyan University. With his coworkers he built a calorimeter for studies on man and designed a bomb calorimeter for measurement of caloric value of foods. He made adjustment for the indigestible fraction in food and the incomplete oxidation of protein in the body and gave the values, widely used ever since, of 4, 9, 4 Calories per gram of carbohydrate, fat, and protein in a mixed diet.

The Congress in 1894 appropriated 10 thousand dollars "to enable the Secretary of Agriculture to investigate and report upon the nutritive value of the various articles and commodities used for human food, with special suggestion of full, wholesome, and edible rations less wasteful and more economical than those in common use."

This work was assigned to the Office

of Experiment Stations under Dr. Atwater, who was designated "chief of nutrition investigations."

From that time forward, biochemists, nutritionists, home economists, and investigators in animal and poultry husbandry at agricultural experiment stations throughout the country have steadily and continuously helped build the newer knowledge of nutrition.

Headquarters for the work were established at Middletown, and Dr. Atwater was made chief. He and his colleagues investigated the diets of hundreds of persons of different occupations and compared the results of similar studies in other countries. They made many experiments with men on digestion and carried on special studies of the nutritive value of cereals, meats, vegetables, fruit, and nuts and the effects of cooking and other forms of preparation on nutritive values.

He and his coworkers demonstrated that the amount of heat—energy—a person develops during a given period is the amount that can be derived from the energy liberated in the oxidation of food materials during the period.

Dr. Atwater studied digestibility of food, made numerous dietary studies, and analyzed many foods. He prepared in 1896 the famous Bulletin 28 of the United States Department of Agriculture. It was the first extensive table of food values ever prepared in this country.

Atwater sought to find what was the best and most economical diet for man. At that time only protein and Calories, as supplied by fat and carbohydrate, were considered of importance, and such foods as green, leafy vegetables and fruit were regarded as expensive purchases or luxuries.

A chapter Dr. Atwater wrote for the 1894 Yearbook of Agriculture has meaning for us today. I quote a few sentences from it:

"Materials for the food of man make up the larger part of our agricultural production and the largest item of our export abroad. Our food production is one-sided. It includes a relative

excess of the fat of meat, of starch, and of sugar, the substances that serve the body for fuel to yield heat and muscular power, while the nitrogenous substances, those which make blood and muscle, bone and brain, are relatively deficient. . . . What is needed is more nitrogen in the soil for plant food, more nitrogen in plants to make better food for animals and man, and more nitrogen in the food of man. Better culture of the soil and better manuring will bring not only larger crops, but crops richer in nitrogen. . . .

"The power of a man to do work depends upon his nutrition. A well-fed horse can draw a heavy load. With less food he does less work. A well-fed man has strength of muscle and of brain, while a poorly nourished man has not."

He defined food as "that which, when taken into the body, builds up its tissues and keeps them in repair, or which is consumed in the body to yield energy in the form of heat to keep it warm and create strength for its work. . . ."

"The most healthful food is that which is best fitted to the wants of the user. . . .

"The cheapest food is that which furnishes the most nutriment at the least cost.

"The most economical food is that which is both most healthful and cheapest.

"To make the most out of a man, to bring him up to the desirable level of productive capacity, to enable him to live as a man ought to live, he must be well fed.

"One of the ways in which the worst economy is practiced is in the buying of high-priced foods. For this error, prejudice, the palate, and poor cooking are mainly responsible. There is a prevalent but unfounded idea that costly foods, such as the tenderest meats, the finest fish, the highest priced butter, the choicest flour, and the most delicate vegetables possess some peculiar virtue which is lacking

in the less expensive materials. . . . The maxim that 'the best is the cheapest' does not apply to food."

LET US GO BACK now for a glimpse at the beliefs and knowledge on which Atwater and other scientists of the 20th century built. Such a quick survey will help us to understand better the growth of the science of nutrition—and the speed with which it has grown.

Back in the days of the Greeks, before the birth of Christ, man's inquiring mind was asking questions about the world in which he lived. The "science" of that day believed that there were four elements—earth, air, fire, and water; four qualities—dry, cold, hot, and wet; and four humors, or liquids, that comprised the body—blood, phlegm, black bile, and yellow bile.

Hippocrates, the father of medicine, taught the value of diet, but he believed in one universal aliment, an idea that prevailed until the early part of the 19th century.

Galen, a Greek physician who settled in Rome in A.D. 164, wrote many books about anatomy, diet, and health. His word was accepted without question through the centuries that saw the decline of Rome, the Dark Ages, and the first light of the Renaissance, until Andreas Vesalius (1514–1564), a Flemish student of anatomy, overthrew some of Galen's ideas and dared to investigate for himself, rather than follow blindly the master's dicta.

One original thinker in Italy tried to study nutrition. He asked the right questions, but he could not get the answers because he had neither a knowledge of chemistry nor the necessary tools. Santorio Sanctorius (1561–1636) day after day sat on his big balance and weighed himself and the food he ate, but could not find the answer to the difference in weight after he had eaten. He has truly been called the father of experiments in metabolism, but it was some 300 years later before investigators could explain the nutrition problem he had posed.

In the 17th century, "the Golden Age of Science," the experimental method began to take hold. The British William Harvey revolutionized our concept of the human body by demonstrating that blood circulates from the heart throughout the body. The Dutch Anton van Leeuwenhoek developed the microscope and studied the red cells or corpuscles of the blood stream. At meetings of the Royal Society, which received its charter in 1662, scientists discussed their experiments and the curiosities of nature they had found.

The 18th century brought the rise of modern chemistry. Joseph Black, a professor at Glasgow, discovered the gas that to us is carbon dioxide. Wealthy, eccentric Henry Cavendish discovered hydrogen. Daniel Rutherford, a Scottish physician, discovered nitrogen. Joseph Priestly, the English minister who was happiest when he was in his laboratory, was credited with discovering oxygen.

Antoine Lavoisier of France, outstanding in his ability to interpret and integrate the new discoveries, showed that the life process is one of respiration and that as oxygen was consumed by the body, carbon dioxide was exhaled. He measured those gases and calculated the body's heat production. He realized that the working man expended more calories and therefore needed more food than those who were less active.

Interest in physiology grew. René Réaumur (1683-1757), a French naturalist and physicist, fed various foods to birds and then, after short periods of time, retrieved the food and studied the changes that had taken place during digestion.

Lazzaro Spallanzani (1729-1799) in Italy experimented on himself. He swallowed linen bags containing meat and bread and withdrew them later by strings attached to the bags. From the changes he found in the partly digested food, he realized that some chemical changes were taking place.

A Scottish naval physician, James

Lind, conducted a carefully controlled experiment, the first of its kind, and demonstrated how to prevent and cure scurvy, "the scourge of the sea," that killed hundreds of sailors on ships taking long voyages. Dr. Lind in 1747 found that lemon juice could cure or prevent this disease; yet it was more than 50 years later before the British Navy required that lemon juice be provided on all ships. Even then no one seemed to realize the significance of the cure; some 150 years later vitamin C was discovered as the anti-scurvy vitamin.

The 19th century was the period of chemical investigation and measurement of respiration and energy use by animals.

Hippocrates had taught that there was one ultimate principle in food, and not till 1834 did this idea change. William Prout, a London physician, published a book, *Chemistry, Meteorology and the Functions of Digestion*, in which he put forward the idea that food contained three staminal principles, which he called saccharine, oily, and albuminous material.

A new era began in 1816 when Francois Magendie, the great French physiologist, discovered that dogs died if given only sugar or oil or butter but would live if given a nitrogen-containing food. Soon Jean Boussingault, a French chemist and experimental farmer, made the first experiment of nitrogen balance with a horse and a cow. Gerrit Jan Mulder, the Dutch physician and chemist, exploring the nitrogen-containing foods, introduced the term "protein" in 1838. He was wrong in what he thought these proteins were, but the name stuck.

The chemistry of the albuminous (protein) substances, as these were first called, began to be understood when some of the "building units" of these complex substances were isolated. The first amino acid, cystine, was discovered in 1810 by the English chemist and physicist William Wollaston when working with kidney stones. He failed to recognize its true chemical

nature. The simplest of all the amino acids is glycine. It was first identified by M. H. Braconnot, the French chemist who obtained glycine as a breakdown product from hydrolysis of gelatin.

By the end of the 19th century, 12 of the 22 amino acids now known to be present in proteins of food had been discovered.

The spotlight was on protein. Organic chemistry developed, and Justus von Liebig, the great German chemist, branched out to develop the new agricultural chemistry that was later to lead to biochemistry.

Studies of nitrogen balance were made on dogs and other experimental animals in attempts to determine the amount of protein they needed. Chemists were busy improving methods of food analysis, and the general belief was that through knowledge of chemical composition of foods one would be able to plan an adequate diet.

The French chemist Jean Dumas evolved an accurate method for quantitative measurement of nitrogen. The protein content could be calculated from it. But it was such a long, painstaking process that not many studies could be made. Then the keen mind of Johann Kjeldahl, a Danish chemist, devised a new and relatively easy method of determining nitrogen in organic matter (1883), and the work could push ahead more rapidly. The availability of equipment and suitable chemical methods of analysis have always been an influencing factor in the development of the science of nutrition.

IN AMERICA, physiology and the study of digestion of food were aided by the work of a backwoods surgeon, William Beaumont. He was on Army duty at Fort Mackinac in Michigan Territory when a gunshot wound of a French Canadian trapper, Alexis St. Martin, gave him an opportunity to show his medical and surgical skill. The trapper's life was saved, but he lived with a hole in his stomach. The

hole let Dr. Beaumont have a living organ for the study of digestion. Patiently and accurately, he made his experiments so that the findings presented in his book, *Experiments and Observations on the Gastric Juice and the Physiology of Digestion* (1833), were unsurpassed until the researches of the Russian physiologist, Ivan Petrovich Pavlov.

Dr. Beaumont might have accomplished more, but Alexis did not like being experimented with. He slipped away to Canada and declined to return. Chemistry was not far enough advanced in Beaumont's day to be able to identify what was in the sample of gastric juice that he sent to the leading chemists to analyze. But digestion was clearly recognized now as a chemical process of breaking down food, and men could begin to find out what it involved.

Next came the study of respiration and calorimetry that led to the measurement of man's energy needs—the first steps to quantitative knowledge of nutritional requirements.

Foremost in this work was Carl Voit, who had learned his chemistry from Liebig and later provoked his former teacher by daring to disagree with some of his findings.

Voit, with the help of Max von Pettenkofer, who had been Liebig's assistant, built an apparatus for the study of respiratory exchanges in man and animals. Between 1866 and 1873, these two men published seven long papers on the metabolism of healthy persons during fasting and at work. Dr. Voit showed that, contrary to current belief, nitrogen metabolism is not increased by muscular work.

One of the greatest of all Voit's pupils was Max Rubner, who continued the calorimetry studies begun under his master teacher. He determined caloric values of 4.1, 9.3, and 4.1 per gram of carbohydrate, fat, and protein.

Rubner also established the law of surface area in basal metabolism from his experiments, which showed that heat production of man in the resting

state is proportional to the surface area of the body. He showed that the law of conservation of energy—which says that energy must have a source; it cannot come from nothing, nor can it disappear into nothing; it only changes form—holds true for the animal world as for the physical. Rubner also demonstrated that fat and carbohydrate are interchangeable in nutrition on the basis of energy value.

An entirely different concept of food values was introduced some 20 years later.

Elmer V. McCollum in 1918 published a book, *The Newer Knowledge of Nutrition*—a title that was used by many workers from then on to describe the change which had taken place in our understanding of nutrition. In that book, Dr. McCollum also introduced a term that has been widely used ever since—"the protective foods." Milk and the leaves of plants, he wrote, are to be regarded as protective foods and should never be omitted from the diet.

The rapid growth of knowledge of nutrition in the 20th century is also illustrated by the book. The first edition in 1918 had 189 pages. It went through five editions, and the latest in 1939 had 684 pages.

The 20th century opened with the general recognition that protein, fats, and carbohydrates as sources of energy and some inorganic salts were the necessary components of the diet.

This, despite the fact that some two centuries earlier, Dr. Lind had shown that because lemon juice would cure scurvy there must be something else in food. Other investigators some 10 to 20 years earlier also had unusual things happen with diets they were using. Christiaan Eijkman, a Dutch army surgeon, discovered that chickens fed polished rice developed a neuritis, like beriberi, which he could cure or prevent by feeding brown rice. He was the first person to produce a dietary deficiency disease experimentally. In Japan, Baron Kanekiro Takaki had found that he could pre-

vent beriberi, which took the lives of many Japanese sailors, by increasing the amount of meat and fish in their diets.

Nicolai Lunin, a young student in a Russian laboratory, found in 1880 that mice thrived on milk, but they died if they were given a mixture of protein, fat, sugar, and ash of milk. These findings could not be explained and attracted little attention in a world that was making rapid progress in chemistry and bacteriology. The time was coming when the limited viewpoint provided by chemical analysis would be replaced by the new biological method.

VITAMINS now are household words, but the term was coined only in 1912 by a Polish chemist who was working at the Lister Institute in London.

Casimir Funk was trying to isolate some substance from rice polishings that would forestall beriberi. He reasoned that if there was something in food that prevented beriberi, scurvy, and pellagra, this something was vital for life.

His laboratory preparation, which was effective in curing beriberi in birds, was an amine compound, and so he coined the name "vitamine." The name caught on.

Support was given to Dr. Funk's suggestion of the existence of vitamins by the work of Frederick G. Hopkins, biochemist in Cambridge University, England. Dr. Hopkins fed rats an artificial diet prepared from constituents of the same nature as those present in milk. He used a diet of casein, starch, cane sugar, lard, and inorganic salts, each constituent as carefully purified as possible. The rats grew for a short time but then drooped and died. A similar group of rats grew normally when they were given as little as 2 cubic centimeters of milk daily in addition to the artificial diet.

Dr. Hopkins showed that it was not a lack of calories that caused the death of the animals, nor was it lack of palatability of the diet—a reason often

given then to explain the failure of growth in animals on special diets. He postulated that there were unsuspected dietetic factors, or accessory food substances, that were essential for health.

Louis Pasteur's brilliant researches of the 1870's helped establish the new science of bacteriology and fixed the germ theory of disease firmly in the minds of scientists.

Cleanliness and sanitation in the handling of food were recognized as essential. But the idea that something not present in food, something lacking, could cause disease was indeed difficult to accept. Men's minds must be ready for the acceptance of new ideas and the findings of research; there was much resistance to the vitamin theory for a decade at least.

Some experiments started at the University of Wisconsin in 1907 were to lead, by halting steps at first, to the actual discovery of the first of the many vitamins with which we are familiar. Rations of the same chemical composition, but each from a different single plant, were fed to cows. The corn-fed animals were sleek, trim, healthy looking after a year. Those receiving the ration from the wheat plant had a rough coat and a gaunt appearance. Those fed the oat plant were midway between. The experiment proved that chemical analysis did not give the complete answer about nutritive values.

Elmer V. McCollum was one of the assistants in those early classic experiments with cows. He was a farm boy from Kansas with a thirst for knowledge and a retentive mind, and he had studied under the great Lafayette Benedict Mendel at Yale University.

Dr. McCollum was given the assignment to try to find what was the cause of the difference in the three rations, which were chemically similar, at least according to the analytical methods then available, although they gave different results.

The young McCollum read and pondered. He came to the conclusion

that he must experiment with the simplest of rations prepared from purified foodstuffs if he was to find the cause of the difference. Because a large amount of foodstuff would have to be prepared and it would take a long time for results to show up in cows, he decided he must use some small animal. He chose the rat, and so started what was probably the first rat colony and first extensive series of experiments with these widely used test animals.

By 1913 Dr. McCollum had found an artificial diet of protein, lactose, starch, and inorganic salts, that, with butterfat, gave good growth. If he used the same diet, but replaced the butterfat with olive oil or lard, the rats failed in growth and health. Some essential unknown factor was thus shown to be present in butterfat. It was first called fat-soluble A and, later, vitamin A.

Further study of the purified diets then being used disclosed that the lactose was not "pure"; when it was further purified, the rats developed polyneuritis, or beriberi, which could be cured by feeding a water extract of rice germ. Thus water-soluble B—vitamin B—was discovered.

Similar findings were reported almost at the same time by Thomas Burr Osborne and Dr. Mendel at Yale, and so opened up the era of what Mendel has called "the little things" in nutrition.

Back in 1907, two Norwegian investigators—Axel Holst and Theodor Frölich—wanted to study what was "ship beriberi," which was common among Norwegian seamen. They tried to produce beriberi in guinea pigs. Like the Princes of Serendip, they found something other than what they were seeking. The diet used produced scurvy in the guinea pigs, and thus by lucky chance a suitable test animal was found. They were able to feed different foods and find which ones would cure scurvy. Once vitamins A and B were discovered, it was realized that the "unknown" in fruit and vegetables must be another vita-

min, and vitamin C was added to the list.

The change in spelling, with the dropping of the final "e", was made in 1920, because it was realized that these unknown substances were not "amines."

The nutritional deficiency diseases scurvy and beriberi thus were known to be curable by proper food. What about rickets, pellagra, and pernicious anemia—would they, too, respond to a vitamin?

A pooling of knowledge gained from the early writers, clinicians, pathologists, experimental nutritionists, and biochemists soon set the investigations of vitamins in high gear.

More young scientists were being attracted by the new science of nutrition and did their study under great teachers at Yale, The Johns Hopkins University, Columbia, and Wisconsin. These young men and women went forth to the colleges, universities, and experiment stations throughout the country to set up laboratories and to continue the search for new nutrients and the study of how they function.

They encountered difficulties. The rats, guinea pigs, chickens, and dogs with which they worked did not all react in the same way, and soon many letters of the alphabet were used up as designations for what were believed to be new factors.

Vitamin D and vitamin E were identified.

By 1926, what had been called vitamin B was found to be at least two separate factors. One was destroyed by heat and was the antiberiberi factor. Another new substance was stable to heat.

Each new discovery made it possible to prepare more highly purified diets and thus lead to more new discoveries, as other deficiency symptoms showed up in animals and the new curative substances were sought—and found.

A young chemist, Charles G. King, at the University of Pittsburgh, in 1932 prepared pure crystals of vitamin C from lemon juice. It was the first of

the vitamins to be isolated in pure form. It was later named ascorbic acid.

Soon others were isolated and identified chemically, their functions and food sources studied, and the amount required daily for maintenance of health and vigor was determined. The old terms of "antiberiberi," "antiscorbutic," and so forth were dropped when it became apparent that the vitamins did much more than just prevent disease. They were essential for health and well-being and functioned as part of many systems of the body.

The latest discovery is vitamin B₁₂ (1948). It was found to be a preventive factor for pernicious anemia, which had been described by Dr. Thomas Addison about 100 years before.

The vitamin story has developed mainly since the 1920's. Vitamins held the spotlight, but many advances were being made in our knowledge of proteins, trace elements, and other aspects of nutrition.

ONLY PROTEIN received much attention at the beginning of this century.

Dr. Atwater advocated 125 grams daily for a laboring man. Rubner had declared that a large protein intake was the right of civilized man, a view that was shared by many persons in temperate climates who enjoyed meat, cheese, and eggs. Those who preferred a vegetarian or a more limited diet strongly advocated a much lower intake of protein, and controversy raged in the early decades. Later discoveries showed that the kind of protein was a key factor, but we still hear of the early differences of opinion.

Russell H. Chittenden, first university teacher of physiological chemistry in this country, helped lay the foundations of nutrition science through his own investigations at Yale University and his training of many men. He published in 1904 his revolutionary studies of groups of athletes, soldiers, and professional men who were maintained in nitrogen equilibrium on what corresponded to 44 to 53 grams of protein for a man of average weight.

Slowly they learned that protein was not just protein—there are many different proteins in food. Thomas Burr Osborne, a chemist at Yale, was a leader in these studies. He learned that not all proteins are equally efficient in promoting growth or maintaining nitrogen equilibrium.

Karl Thomas, of Germany, introduced in 1909 the term “biological value” of protein and a formula for determining it. Basically, the biological value of a protein means the percentage of nitrogen retained by the body. Comparisons of many proteins were made in this way by feeding experiments with animals and a few similar studies with human beings.

The biological value of a protein was seen to be related to the composition of amino acids in it. Frederick G. Hopkins at Cambridge University was a pioneer in these studies. He and Sidney Cole in 1901 had discovered a new amino acid, tryptophan. Later, when Dr. Hopkins and his coworkers fed mice a diet with casein as the sole nitrogen-containing constituent, the animals flourished. They died when zein, a protein from corn, replaced casein. If tryptophan was added to the zein, however, the mice lived but did not grow.

Dr. Osborne was joined in 1909 by Dr. Mendel at Yale. They were “the most fertile combination of minds ever directed toward studies of nutrition.” They studied almost every phase of nutrition, especially protein and amino acids, and conducted feeding experiments with rats that led to the discovery of vitamins A and B. They measured the biologic value of isolated proteins and showed that amino acids were the limiting factors. In history-making experiments in 1915 they showed that gliadin, a protein in wheat, would maintain life but would not promote growth in rats unless lysine was added and that zein must be supplemented with tryptophan and lysine for life and growth.

At this time proteins were described as being “complete” (they were ade-

quate to maintain life and promote growth) and “incomplete”—that is, they lacked certain amino acids. The concept of quality as well as quantity of protein thus was introduced.

More amino acids were discovered. Nineteen were known then to occur in food proteins. The next step was to find whether they were essential in the diet. Some were hard to get in pure form and in amounts sufficient to feed to test animals.

William C. Rose, one of Dr. Mendel's students, by 1930 at the University of Illinois was able to combine the 19 amino acids as the sole source of protein in diets for rats. The animals failed to grow. Something was still lacking. Because casein or gelatin added to the diet gave good growth, he concluded that some other amino acid, rather than a vitamin or mineral, was the missing factor.

A search for the new amino acid began. It turned out that the new compound was closely tied to another amino acid, isoleucine, and so was difficult to separate and identify, but 4 years of patient work on the problem finally yielded the answer. The new amino acid essential for growth of rats was identified in 1934 and was named “threonine” because of its close relationship to the sugar threose. Continuing his protein researches with mixtures of pure amino acids, Dr. Rose was able by 1938 to prove that nine were essential for normal rate of growth in rats. If arginine was omitted, animals grew at about two-thirds the normal rate—an indication that the organism would synthesize this amino acid but not at a rate that would permit normal growth.

Amino acids could then be grouped as essential and nonessential—needed and unneeded. The next step was to find whether people needed these amino acids. With young men as volunteer subjects, Dr. Rose learned that eight of the amino acids are essential to maintain nitrogen equilibrium.

He then set for himself the task of determining exactly how much of each

was required each day. These were the first long-continued series of studies in which human beings were maintained on diets of purified nutrients. Patiently and persistently, the work went forward, until by 1955 Dr. Rose presented data for the recommended daily intake of each of the amino acids essential for people.

Investigators in many laboratories have been at work since 1930 on the protein problem, including the nutritive value of individual proteins and the specific function of individual amino acids.

Protein has been found to be the material for building muscle and body tissue, and to be part of the hemoglobin molecule in red blood cells. Enzymes and hormones have been crystallized and found to be derived from proteins. Enzyme systems contain protein. Antibodies present in the blood stream, an aid in resistance to infection, are protein in nature.

We usually discuss pellagra along with the vitamins. A "pellagra-preventive vitamin" was sought in the early 1920's. The search continued until 1937, when Conrad Elvehjem, of the University of Wisconsin, fed nicotinic acid (which had been on the chemists' shelves for a long time) to dogs with blacktongue, a disease comparable to pellagra in humans. Nicotinic acid cured the blacktongue, and soon was found to be effective in treating human pellagra. Nicotinic acid was added to the list of known vitamins. Its name was changed to niacin to avoid confusion in the mind of the public.

But the story of the fight against pellagra belongs with the proteins. Investigations were carried on by Joseph Goldberger throughout the South, where pellagra was serious from early 1900's till the late 1930's. He found that certain protein-rich foods prevented or cured pellagra. The complexities of this relationship were difficult to unravel and illustrate the interrelationship between nutrients. The answer was found not long ago: The amino acid tryptophan can be

converted to niacin. Approximately 60 milligrams of tryptophan are equivalent to 1 milligram of niacin.

Problems of metabolism of protein and its requirement are still being investigated.

Attention also has centered on world problems of nutrition—especially on the nutritional disease, kwashiorkor. The first description of this disease of young children was given in 1933, and attempts to identify the cause have gone on ever since. Kwashiorkor is prevalent in the Tropics and in many poor countries where carbohydrate foods form the bulk of the diet and protein-rich foods are unavailable or too costly. "Protein malnutrition" often is used as the term for kwashiorkor, but present knowledge indicates that they are not synonymous.

Kwashiorkor may be due to a deficiency in the kind and the amount of protein or of many of the other essential nutrients. The advances since 1900 in our knowledge of proteins and amino acids have centered attention on people the world over who do not get enough protein. We also know we need to study the vegetable proteins further.

FATS AND OILS have been foods since ancient times, but not until 1814 did a chemist, Michel Eugene Chevreul of France, discover that fats are made of fatty acid and glycerol. He also named margarine.

A century ago heated arguments went on over whether the animal body could change carbohydrates into fat. Experiment was the only way to find an answer. Fat-free diets were fed to pigs, ducks, and geese. Analysis of the carcasses later disclosed the presence of fat in the body; it could have arisen only from the carbohydrate of the diet.

The use of the calorimeter demonstrated that fats have two and one-fourth times the caloric value of carbohydrate and protein. By the beginning of the 20th century, it was accepted that fats and carbohydrates could be used interchangeably in the diet. It was thought therefore that fats were

not essential in the diet. Fats were consumed in large amounts because of their flavor and satiety value, but comparatively little nutritive importance was attached to them, except for their energy value. Then in 1915 came the startling discovery that certain fats, such as butter, were sources of the newly discovered vitamin. Soon other fat-soluble vitamins were discovered.

New interest was aroused in 1929 when scientists observed that rats kept on a fat-free but otherwise adequate diet (with vitamins supplied in other preparations) did not maintain health. The animals lost hair from the body and developed a skin disease and necrosis of the tail. This condition could be prevented by feeding fatty acids that were highly unsaturated in structure. Linoleic acid was identified as the essential fatty acid. Linolenic and arachidonic acids serve the same function. This new knowledge made it possible for researchers to prepare experimental diets, which led to the discovery of more of the vitamins. Once again, interest centered on the vitamins in nutrition.

The high content of fatty substances in the thickened artery walls that is often associated with heart ailments has again aroused interest in the possible relation of dietary fat to those conditions. Much work is being done on fats, the amount and chemical nature of the fats, and the fatty acids that should form part of man's daily diet. Perhaps there is yet to be found a pattern of the kind and amount of fatty acids needed in the diet, as was done for amino acids.

INORGANIC ELEMENTS—or mineral constituents, ash, or inorganic salts, as they have been called—were known a century ago to be essential for plant-life. Farm animals did not thrive if common salt was omitted from their diet.

At the beginning of this century, Henry C. Sherman began studies on calcium, phosphorus, sulfur, and iron in human nutrition, first at Wesleyan

University under Dr. Atwater and later at Columbia University. These elements were recognized as essential in the diet, and many experiments were conducted to try to determine just how much of each was needed, exactly how they functioned in the body, and how they were affected by food preparation. Some of these questions are not yet satisfactorily answered.

Doubt existed for a time as to the form of these mineral elements, but belief in the special virtues of organic combinations, especially of phosphorus and iron, gradually gave way to the recognition that inorganic combinations were equally well utilized.

By 1930, as newer techniques and apparatus made it possible for chemists to measure minute amounts of certain inorganic substances, the significance of the trace elements in nutrition was recognized.

Iodine had been identified a century earlier. In the 1920's it was identified as an essential nutrient. The thyroid gland at the base of the neck enlarges when it is deprived of iodine.

The condition is known as simple goiter. In the Great Lakes area, where iodine has been leached out of the soil and so is not available in food or drinking water, goiter used to be a common occurrence among children, especially girls.

One of the earliest large-scale controlled human experiments was conducted by David Marine and O. P. Kimball in 1921 with 6 thousand schoolchildren in Akron, Ohio. They showed that children given iodine in drinking water did not develop goiter; a large proportion of those not so treated did develop this condition. A more effective way of providing a readily available and safe supply of iodine for all people was developed later by adding potassium iodide to table salt. Use of this salt has always been on a voluntary basis, but it provides a wise public health measure available to all people.

Investigators in the University of Wisconsin in 1928 found that pure

iron salts were ineffective in curing anemia in rats and that small amounts of copper had to be present in the diet before the iron could be utilized.

Manganese, magnesium, and zinc were next added to the list of elements that are needed to maintain growth and health in experimental rats.

Cobalt was found necessary to prevent disease in cattle and sheep (1935). With the discovery of vitamin B₁₂ (1948) and the later chemical identification of cobalt as one of its constituents, this element has joined the list of those which are known to be essential for people.

These are the major nutrients that have been identified so far.

The story of nutrition is more than one of discoveries of new compounds needed by the body, however.

The problems of nutrition continue to grow more complex. New discoveries reveal that there is close interrelationship between many of the nutrients. Numerous factors affect the availability of the different nutrients as they exist in food. The biochemical individuality of each person must be kept in focus in providing for man's nutritional needs.

Food nutrients are converted into body structure. For a long time it was thought that the body material, especially the fat deposits, was more or less stable.

How could one tell? It was possible to analyze and know exactly what was taken in by mouth and what was excreted, but what happened inside the body was pretty much unknown.

This was so until the early 1930's brought the discovery of heavy hydrogen and heavy nitrogen by Harold C. Urey, an Indiana boy who became a professor in Columbia University and in 1934 won the Nobel Prize for chemistry.

His discovery was put to work by biochemist Rudolf Schoenheimer, who incorporated heavy hydrogen into fatty acids and fed them to mice. By sacrificing the animals, he could de-

termine where the heavy hydrogen was deposited. He found that the fatty acids of the stored fats are constantly transported to and from organs. They merge indistinguishably with the fat from the diet and are converted into other fatty acids of both longer and shorter chains. Only the essential unsaturated fatty acids did not take up heavy hydrogen—thus further confirming the earlier finding that the unsaturated fatty acids cannot be synthesized in the body but must be supplied in food.

Another series of experiments was made in a similar way. Heavy nitrogen was used as part of the amino acids fed to mice. As with fats, there was a rapid interchange between dietary amino acids and those of the blood and tissues. The amino acid lysine was the only one that did not take up heavy nitrogen from the "labeled" amino acids. Dr. Schoenheimer demonstrated that the body constituents were in a dynamic state. Another new concept of nutrition was introduced.

Radioactive isotopes of other elements—calcium, phosphorus, iron—are now available, valuable tools for following the pathway of nutrients within the body.

DIETARY STUDIES on man have been carried out through the ages, and I mention some examples to show progress by this avenue of study. Most of the nutrition studies have been made on experimental animals. One cannot deliberately deprive man of essential foods, but history and geographical and economic circumstances have provided opportunities for the experimental study of man.

Sanctorius in the 17th century sought an explanation of metabolism as he weighed himself and his food.

The outcome was a book of aphorisms—a happier ending than the one a young physician, William Stark, had in the 18th century. He was a healthy young man of 29, with a desire to find the effect of diet on health. He ate carefully weighed amounts of bread

and water, and added various other foods one at a time. He fell ill in a few months and died from what in the light of today's knowledge was probably severe vitamin deficiencies.

James Lind was more fortunate. His classic experiment was the first clinically controlled one and showed that lemon juice cured scurvy.

Toward the end of the 19th century, Max Rubner in Germany, Lyon Playfair in England, and Wilbur O. Atwater in the United States made many studies of diets. They reasoned that groups that were vigorous and healthy surely had adequate diets. By analysis of diets of these groups, they believed they could find what was an adequate intake of calories and protein.

Atwater recommended 3,400 Calories and 125 grams of protein for a man who does moderately active muscular work. He considered fat and carbohydrate to be interchangeable as a source of calories.

The newer knowledge of nutrition was well established by 1926, and adequate human diets could readily be obtained from natural foods.

The inquiring mind of Dr. H. C. Corry Mann, an English physician who was in charge of a boys' home, led him to wonder if he could improve what was considered by all standards of the day to be an adequate diet. One group of his boys remained on the regular diet. Six other groups received, respectively, additions of sugar, butter, margarine, casein, watercress, and milk. All the groups that got the extra items increased more in weight and height at the end of a year than the group on the regular diet. The group that got milk made far greater gains.

Later discoveries of vitamins and further knowledge of nutrients have contributed some of the answers regarding the value of milk as a food. This study again demonstrated the value of the concept introduced early in the century by Dr. McCollum that biological investigation provides information that cannot be obtained by chemical analyses.

Another study was that of Lord John Boyd-Orr and his coworkers in 1931 of the health of two African tribes living in the same area but with different food customs.

Physical and medical examinations, blood analyses, and careful examination of food intakes were made on several thousand tribesmen. The Masai tribe was a pastoral group that lived mainly on milk, meat, and raw blood—a diet relatively high in protein, fat, and calcium. The Akikiyu were agriculturists living on cereals, roots, and fruit—a diet relatively high in carbohydrate and low in calcium. The Akikiyu had a higher incidence of bone deformities, dental caries, anemia, pulmonary conditions, and tropical ulcer. The full-grown Masai males averaged 5 inches taller and 23 pounds heavier and had greater muscular strength than their neighbors.

Once again, the evidence suggests that laboratory findings about nutritive value of foods are borne out by direct studies of human beings.

Further emphasis of the importance of nutrition was given by the studies of Dr. Frederick Tisdall and coworkers in Toronto, who in 1941 found that the physical condition of infants at birth was markedly superior when the mothers had received an adequate diet during pregnancy.

The findings were verified in 1943 by Dr. Harold Stuart and Mrs. Bertha Burke in Boston. They took records of 216 pregnant women whose diets could be classed as good, fair, poor, and very poor. The health of each baby reflected the quality of the mother's diet. Most of the infants born to mothers who had good or excellent diets during pregnancy were in good or excellent physical condition at birth. Infants born to mothers on poor diets were mostly in fair or poor physical condition, stillborn, or prematurely born. The poor diet during pregnancy did not appear to affect the mother's health, but it did affect the health of the infant. The amount of protein in the mother's diet also was correlated

with the weight and length of the infant at birth.

SCIENTISTS have wondered for a long time whether nutrition affects the length of a person's life.

Luigi Cornaro, a Venetian of the 16th century, was overindulgent in his youth, but after the age of 40 he kept to a strict dietary regimen. The results were fine for Cornaro; he lived to be 100. In his old age he wrote enthusiastically of the joy of living.

Science demands better evidence than that, however.

It is difficult, if not impossible, to study longevity in relation to diet of man under controlled experimental conditions; no one investigator lives long enough to complete such a study. But if results from experimental rats can be applied to man (and there is evidence that such findings are in many cases applicable), then Henry C. Sherman's experiments at Columbia University have provided an answer.

Beginning in 1920, Dr. Sherman started two series of rats on different diets. Diet A, of dried whole milk and ground whole wheat, was adequate for growth and reproduction. Diet B had a higher proportion of milk powder, and so was better. Succeeding generations from the original animals were maintained on the same two diets. By 1949, the 70th generations were still thriving. This is somewhat like taking two families before the time of Julius Caesar and studying their descendants continuously up to the present time.

Diet A was adequate for growth and reproduction through all the generations of rats. On diet B, the better diet, the animals showed differences which were statistically significant: A more rapid and efficient growth, earlier maturity, longer duration of reproductive life, greater success in rearing of young, and increased length of life.

Other studies by Dr. Sherman showed that the increased vitamin A

and calcium from the added milk powder in diet B definitely contributed to the improved growth and longevity of these animals.

The depression years provided clinical material for the study of nutritional deficiencies in man. They also aroused nationwide concern that our people be adequately fed.

What is an adequate diet is hard to say. Lord Boyd-Orr has defined health as a "state of well-being such that no improvement can be effected by a change in diet." But what kind of a diet will maintain such a state of health?

Hazel K. Stiebeling, now Director of the Institute of Home Economics in the Department of Agriculture, was one of the scientists who considered the problem of the hungry 1930's and set up a working pattern of amounts of nutrients and food required daily for individuals of different ages, sex, and activities. Dr. Stiebeling guided a nationwide study of food consumption of a representative sampling of the population of the United States in the mid-1930's. The diets were evaluated in terms of adequacy as compared with the standard of requirements. The publication, "Are We Well Fed? A Report on the Diet of Families in the United States," aroused widespread concern and led President Franklin D. Roosevelt to call the National Nutrition Conference for Defense in May 1941. At the same time the National Academy of Sciences-National Research Council appointed a Committee on Food and Nutrition to develop a table of "Recommended Daily Allowances for Specific Nutrients."

War problems provided a further stimulus to the study of nutritional needs of all people. Representatives of 44 nations met at Hot Springs, Va., in 1943 to consider ways and means by which each country might increase the food resources and improve the diets of their people. From this conference came the meeting in 1945 in Quebec when the Food and Agriculture Organization of the United Nations was

established. It has done much through the years to study malnutrition, determine nutritional needs, and promote food production and improvement of diets of people all over the world.

Enrichment and fortification of food was another milestone in nutrition progress. Enrichment was made possible in the 1940's by the chemists' ability to prepare pure nutrients in inexpensive forms and was made necessary by the findings that the average American diet of that period was inadequate.

I have mentioned the incidence of goiter and its prevention by the addition of small amounts of iodine. Potassium iodide was added to table salt and made available to the public on the grocery-store shelves in 1924 and the benefits of this public health measure have been demonstrated.

Vitamin A has been added to margarine to make it a good source of vitamin A. Such fortification is mandatory in some States, and margarine with 15 thousand International Units of vitamin A per pound is available in most parts of the country.

The Danes first realized the need for adding vitamin A in this way. During the First World War, practically all the butter of Denmark was exported. Subsequently an eye ailment was observed in young children and was recognized as a vitamin A deficiency. As a preventive measure, vitamin A concentrates were added to margarine. Other countries adopted the practice. The Council on Foods and Nutrition of the American Medical Association approved it in 1939, and it has since been advocated by the Food and Nutrition Board.

The discovery of vitamin D as the antirachitic vitamin and the recognition of fish-liver oils as a potent source led to the advice that babies should receive cod-liver oil or some concentrate of vitamin D. Prevention of rickets and development of strong bones in young children depend on an adequate intake of calcium and phosphorus, as well as vitamin D, and therefore forti-

fication of milk with vitamin D was begun in the early 1930's. The Council on Foods and Nutrition of the American Medical Association approved the fortification of milk with 400 International Units of the vitamin per quart.

Considerable evidence had accumulated by 1941 that many American families were consuming diets that were inadequate in thiamine, riboflavin, niacin, and iron. Because we also were concerned with the problems of war in Europe, the National Nutrition Conference for Defense was called in May of that year. The Government was studying proposals to add some vitamins to flour and bread. A Committee on Food and Nutrition (later called the Food and Nutrition Board) had been established in 1940 to provide direction for the national nutrition program. The committee proposed the use of the term "enriched" and set up minimum and maximum limits for the enrichment of bread and flour with thiamine, riboflavin, niacin, and iron. With the support of the millers, enriched flour became available to the public and was used by the Army and Navy. Riboflavin, however, was not available in adequate amounts to use until the end of 1943.

The bread-and-flour-enrichment program has been a controversial one. Some have maintained that the public should be educated to the use of natural foods that would supply all nutrients, but experience of centuries has shown that people are reluctant to change their food habits and that education regarding food choices is a slow process. More than half the States require the enrichment of flour and bread. South Carolina was the first to do so.

Dietary studies give evidence of the nutritional improvement of the food intake of various groups and clinicians have reported declines in nutritional deficiency symptoms. But there have been improvements in family income and family food expenditures since the enrichment program began and

these are contributing factors. Nevertheless, all experimental evidence to date shows that nutritional improvement of diets brings improvement in health. Especially is this so when the article of food is a staple.

FROM THE MINDS of men have come the ideas and from the laboratories have come the proof (and sometimes disproof) of the ideas on which our knowledge of nutrition is based. Nutrition laboratories are expensive to maintain.

Therefore the story of progress would not be complete without reference to some of the organizations and agencies that have contributed funds for support of research in nutrition and have provided opportunities to know the work of others through professional meetings and publications.

Our account of how the study of nutrition emerged as a science began with Wilbur O. Atwater and his research in the Office of Experiment Stations. Experiment stations in every State now carry on the search for knowledge. Other divisions of the Department of Agriculture are engaged in a wide variety of basic and applied problems related to nutrition. Chief among them is the Institute of Home Economics, which was established in 1923 as the Bureau of Home Economics.

The United States Public Health Service also has made an outstanding contribution. The story of the fight against pellagra and the use of iodine to prevent endemic goiter have been told. Men of the Public Health Service were in the forefront.

Three professional organizations have among their members many men and women who were the students of Mendel, McCollum, and Sherman and who have carried on research and teaching in all phases of nutrition. These organizations are the American Home Economics Association (1909), the American Dietetic Association (1917), and the American Institute of Nutrition (1933).

The Food and Nutrition Board of the National Academy of Sciences-National Research Council (1940) has guided the application of the science of nutrition through its recommended dietary allowances. The members of the Board also prepare bulletins summarizing and interpreting current research in nutrition.

Nutrition research workers in the laboratory have been greatly aided by grants from the Williams-Waterman Fund (1940). This fund was named for Robert R. Williams, "the father of enrichment," who devoted 26 years to the search for thiamine. Robert E. Waterman was Williams' partner in the last 12 years of his search. Together they found the way to make thiamine so cheaply that it can be used for enriching bread, flour, cornmeal, and rice.

Another important source of financial aid to the research works in nutrition is the Nutrition Foundation (1941). Food manufacturers throughout the country support the foundation, and Dr. Charles G. King, who isolated pure vitamin C in 1932, in 1942 became director of its program of aid for research and dissemination of information about nutrition.

Alone and in teams, in private laboratories and the State experiment stations, and in colleges, universities, clinics, medical schools, and industrial firms, men and women in this and many other countries have sought the answers to the intricate problems of man's health and well-being as influenced by his food. Great progress has been made. Much remains to be learned, however, and that is the challenge we have now.

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